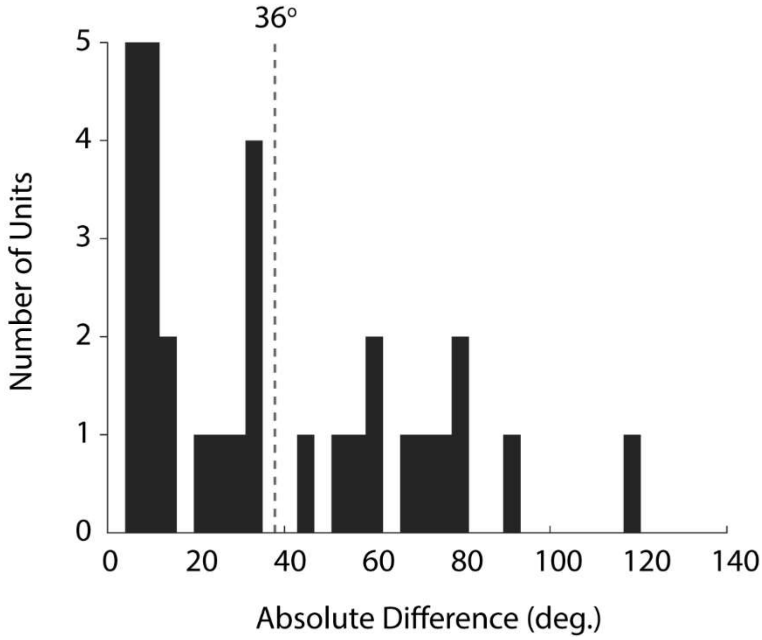
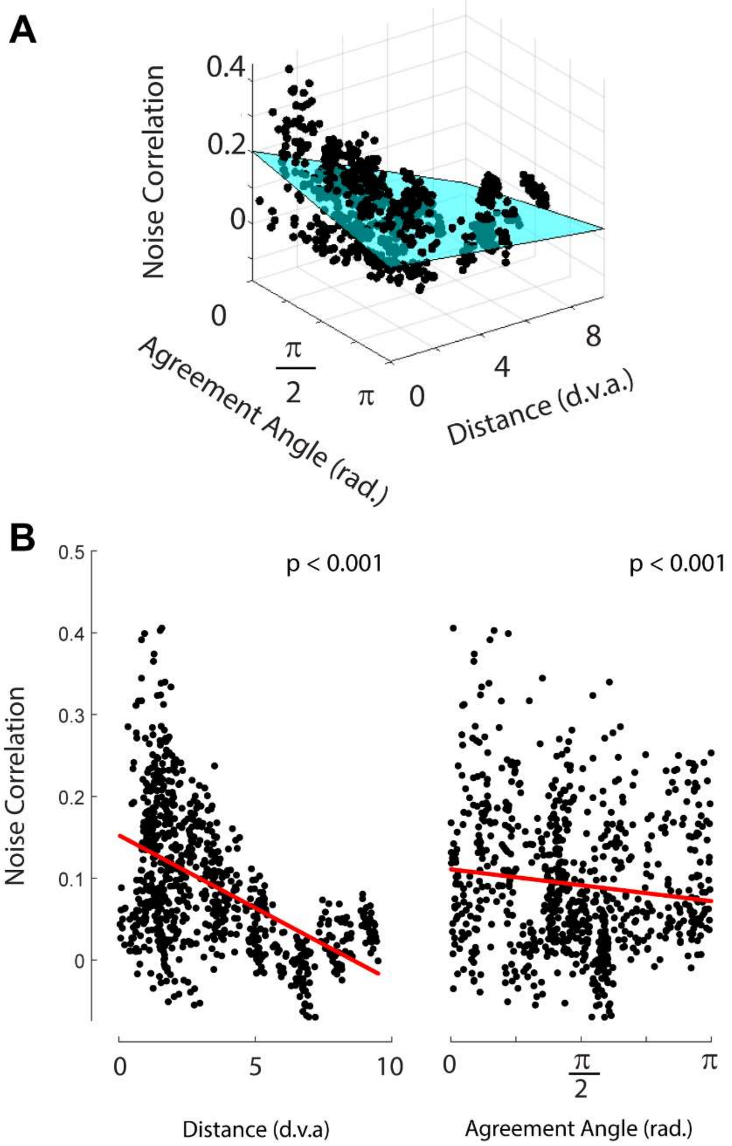
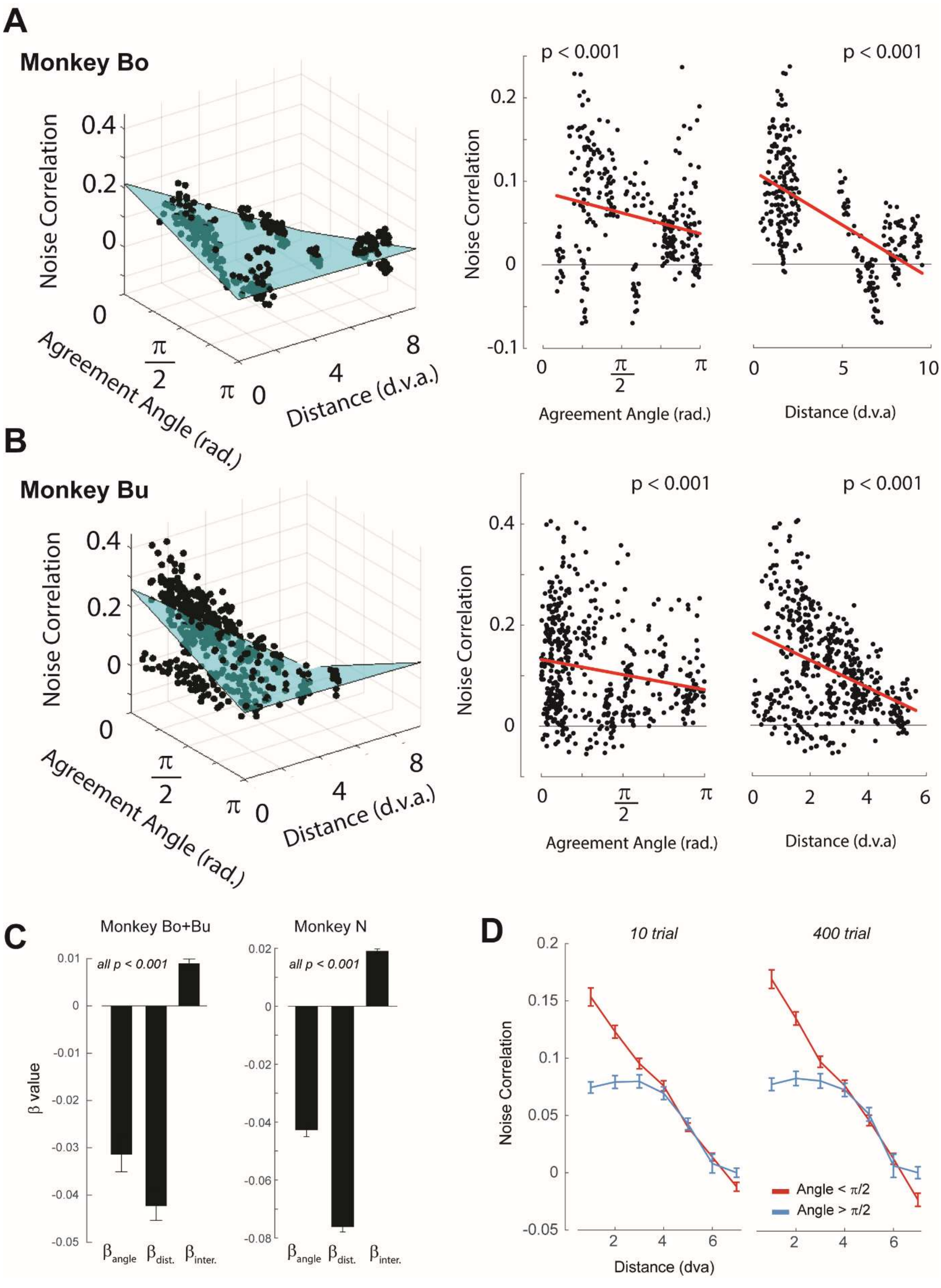
Supplementary Information



Supplementary Figure 1. Border-ownership versus orientation preference. The histogram shows the absolute circular difference between the preferred border-ownership angle estimated at the preferred orientation of the V4 recording sites and BO_{pref} in monkeys Bo and Bu. This difference can range up to 180 degrees (e.g. one method estimates a BO tuning to the left of the RF at 90° and the other estimates a BO tuning to the right, or 270°). The mean difference was 36°.

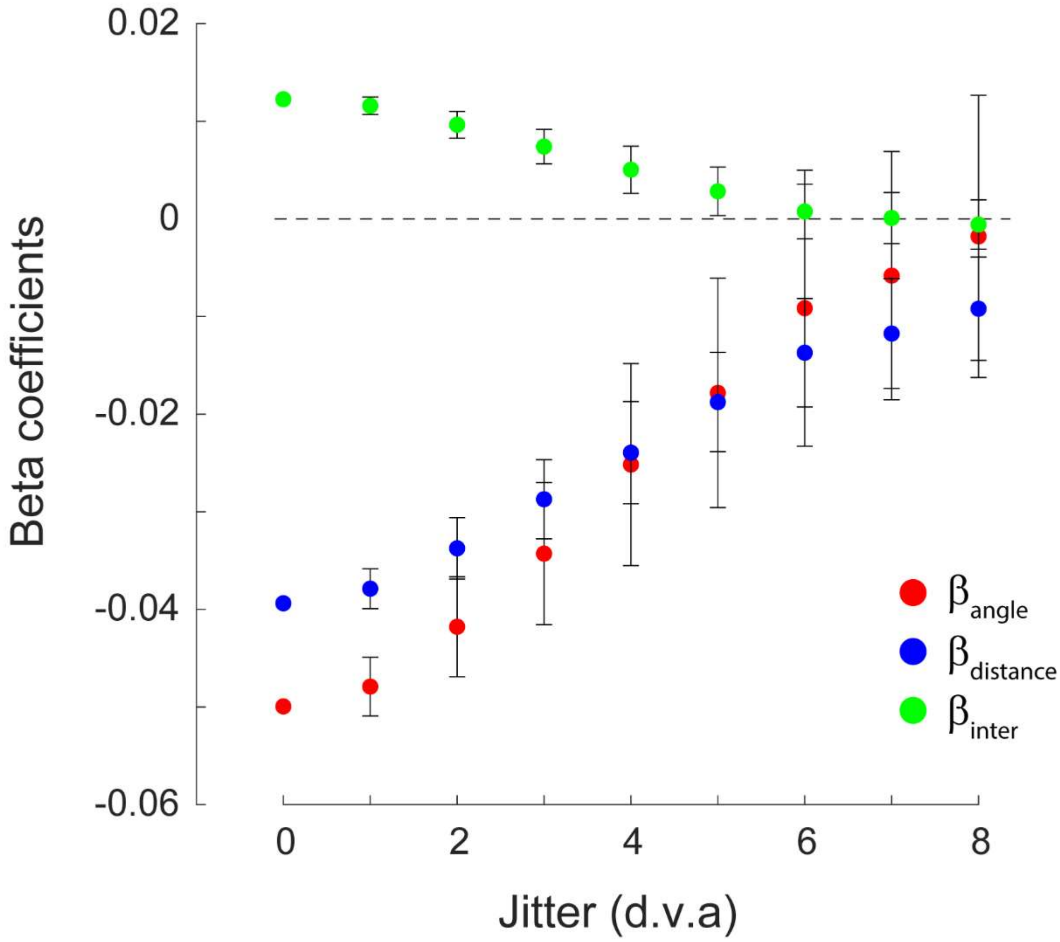


Supplementary Figure 2. Regression analyses using classical BO measures. A-B. The regression plane (A) and marginal distributions (B) from an analysis using the classical BO measure. Conventions as in Figure 4A,B. In the main analyses of the data of monkeys Bo and Bu we measured BO preference using BO_{pref}, the summed vector of responses at all tested border-orientations. Classically, BO preference has been tested at the preferred orientation of the cell (see Methods). To determine if our choice of BO-preference measure affected our conclusions we reran the analysis using the classical BO measure. We fitted the responses to the BO tuning stimuli with a circular Gaussian (Equation 5 in Methods). We included 21 classically tuned BO units in Monkey Bo and 9 units in monkey Bu. The regression plane and marginal distributions were similar to those of the main analysis. The effect of agreement-angle, distance on the noise-correlation and their interaction were significant (all $p < 0.001$) with values that were similar to those in the main analysis.

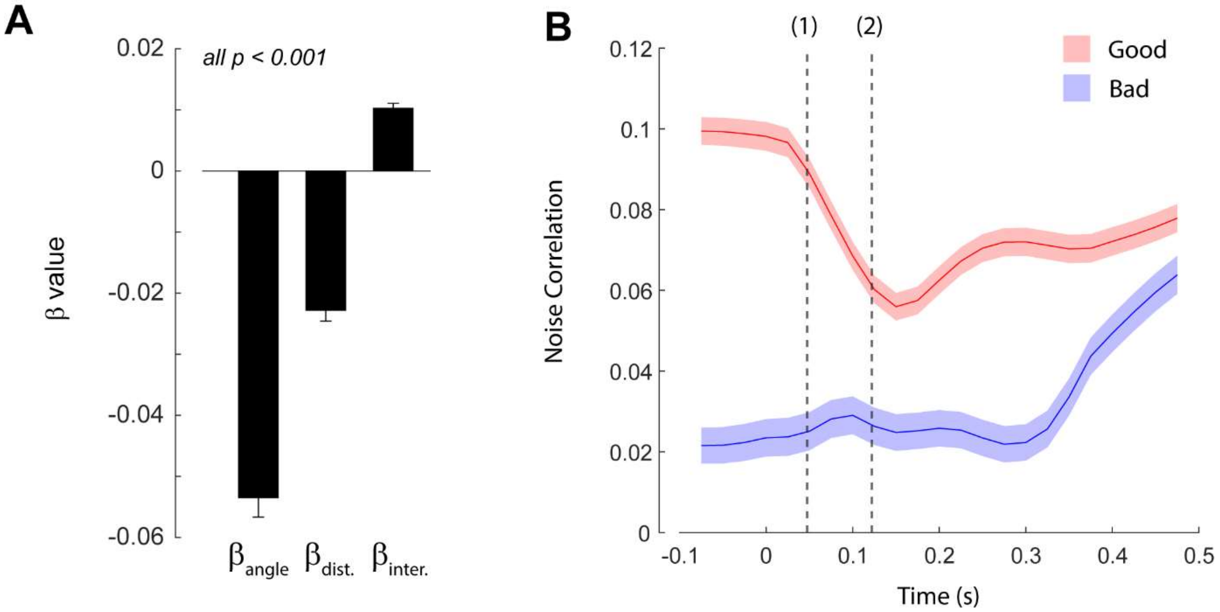


Supplementary Figure 3. Regression analyses for monkeys Bo and Bu. A-B: Conventions as in Figure 4A,B. n = 306 pairs in monkey Bo and 501 pairs in monkey Bu. **C.** Beta coefficients from a Linear Mixed Effects model. Noise correlations are higher within electrodes on the same array and so we reran the linear models using a hierarchal statistical model in which electrodes were grouped within arrays. We used Linear Mixed Effects (LME) models with random intercept terms added for the array

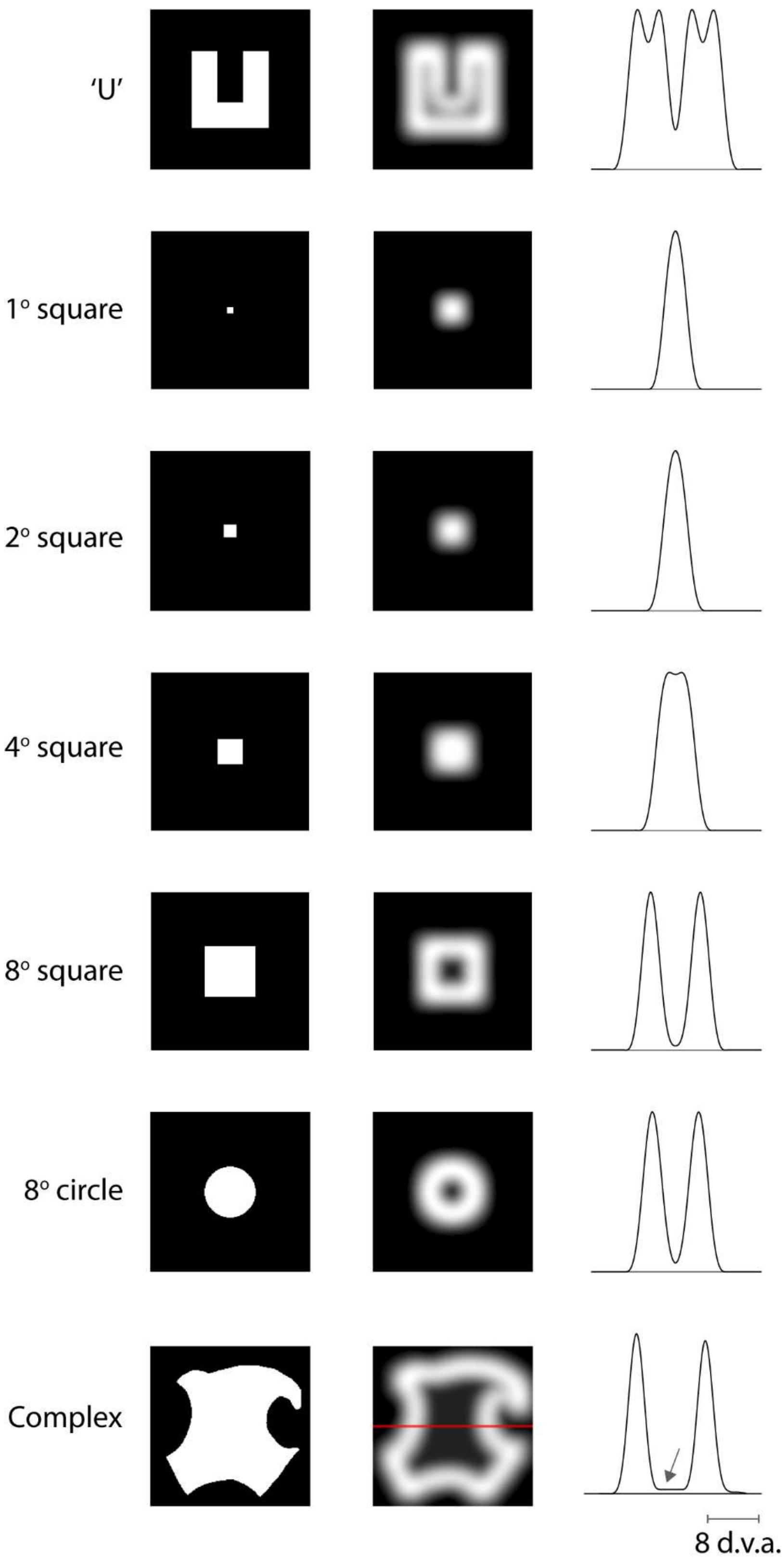
ID. Note that two separate random intercepts were added, one for the V1 array ID and one for the V4 array ID as the effect of grouping within array is likely to differ between areas. The model included data from monkeys Bo and Bu (left panel) or monkey N (right panel). The graph shows the fixed-effect coefficients, compare with Figure 4C. **D.** Replication of Figure 4D for different smoothing windows. Two different robust LOESS smoothing windows were used to smooth the baseline activity level before calculating noise correlations. The 10 trial smoothing window (left panel) slightly reduced noise correlations but had no effect on the relationship between Agreement angle, RF distance and noise correlation.



Supplementary Figure 4. The effect of jittering the V4 RF location on the regression model in monkeys Bo and Bu. To assess how sensitive the regression model was to the exact location of the V4 RF we determined the agreement angle and Euclidean distance 100 times while jittering the position of the V4 cells' RF randomly in the X and Y directions. Jitter values were drawn from a uniform distribution between –x/2 and +x/2 where x is the value indicated on the x-axis. We evaluated the regression model with the jittered data. The graph shows the mean and standard deviation of the beta-coefficients for agreement angle (red), RF distance (blue) and the interaction (green). Beta coefficients were significantly different to zero at jitter values up to 4 degrees ($p < 0.05$).



Supplementary Figure 5. Evoked noise correlations. A. Beta-coefficients from a linear model examining the relationship between agreement angle, RF distance and the sustained response of V1 and V4 units during presentation of the BO-tuning stimuli in monkeys Bo and Bu (100-500ms). A more complex, 4 predictor model is shown in Table 1. **B.** We re-examined the noise correlations observed during responses to the figure-ground stimuli (Figure 5) in sliding time-windows of 50ms duration. The shorter time-window leads to lower correlations overall[1]. We limited the analysis to trials in which the V4 cell was well driven by the border-orientation (border-orientation < 90^o). The dashed lines mark (1) the onset of BO-tuning and (2) the onset of FBM. The onset of the visual stimulus caused a reduction in the difference in noise correlation between the V1-V4 pairs with RFs in good and bad alignment. The visual stimulus reduced the noise correlation for good-alignment pairs. After the onset of FBM the difference in noise correlation between good and bad pairs became stronger again, presumably because V1 and V4 now engaged in recurrent interactions.



Supplementary Figure 6. Responses of an extended model to more complex forms. The model described in Figure 7 was constructed with only the 4 canonical BO ownership directions. We also tested an extended model include a larger range of border-ownership preferences (24 values in 15° steps) and examined the response to a range of figure sizes and shapes. The resolution of the figure-ground pattern observed in model V1 had a lower limit, meaning that responses to a 1° or 2° square were indistinguishable from each other. More complex shapes were well captured by the model, and a small amount of residual figure-ground modulation remained for even quite large shapes (arrowed, the red line indicates the height of the cross-section), reminiscent of human perception in boundary-spreading illusions such as the watercolor illusion [2].

Effect	Estimate	p-value
Angle	-0.07	$<10^{-12}$
Distance	-0.01	0.2
Border	0.007	0.5
FB	0.12	$<10^{-4}$
Angle x Distance	0.007	0.01
Angle x Border	0.02	0.0004
Angle x FB	-0.02	0.21
Distance x Border	-0.004	0.17
Distance x FB	-0.03	0.001
Border x FB	-0.08	$<10^{-7}$
Angle x Distance x Border	0.0001	0.93
Angle x Distance x FB	0.018	$<10^{-5}$
Angle x Border x FB	0.017	0.03
Distance x Border x FB	0.024	$<10^{-6}$
Angle x Distance x Border x FB	-0.012	$<10^{-8}$

Supplementary Table 1. Four predictor linear model for evoked noise correlations in monkeys Bo and Bu. We implemented a linear model examining the effects of the relationship between the border of the figure and the V4 cell's tuning preference ('Border') and whether the V1 RF fell on the figure or background ('FB') as extra predictors in the model in addition to the agreement angle ('Angle') and RF Distance ('Distance'). We observed a significant 4-way interaction between the predictors ($p<10^{-8}$), which indicates that we could not simplify the model further. The strong two-way interaction between Angle and Border is presented in Figure 5C. This interaction relates to how the difference in the strength of noise correlations between good and bad pairs depends on the whether the V4 cell is being driven by its preferred or non-preferred orientation. The strong Border x FB effect is explored in Figure 5D, showing that the influence of figure/ground in V1 on the noise correlations is only pronounced when V4 neurons are well-driven by their preferred border orientation.

References

1. Cohen, M. R. & Kohn, A. Measuring and interpreting neuronal correlations. *Nat. Neurosci.* **14**, 811–819 (2011).
2. Pinna, B., Brelstaff, G. & Spillmann, L. Surface color from boundaries: A new ‘watercolor’ illusion. *Vision Research* **41**, 2669–2676 (2001).